THE PENNSYLVANIA STATE UNIVERSITY
ENERGY AND MINERAL ENGINEERING
ENVSE 408 CONTAMINANT HYDROLOGY
ASSIGNMENT 2

Site characterization is currently underway to determine the potential suitability of Yucca Mountain, NV, as the Nation's civilian high level radioactive waste repository. The current plan is to create an underground repository at a depth of 350 *m* in partially saturated Topopah Springs volcanic tuffs. The repository will be a series of parallel drifts (tunnels) arranged within a plane at the 350 *m* elevation each containing steel cannisters of heat-generating waste. The large thermal loading is expected to produce a thermal profile similar to that illustrated, decreasing from about 160^o C at the repository horizon to below boiling (98^oC) about 100 *m* away. Assume this to be the maximum dry-out at between 600 and 1000 years. Above the dryout zone, condensate will collect, having been driven by buoyancy of the water vapor in fractures, and then imbibed into the matrix surrounding the fractures. Following the peak thermal loading, the dryout zone will contract as the condensate refluxes to the repository.

The repository is laterally extensive (700 m $\times$ 2800 m) compared to its depth (350 *m*), so these calculations may consider a one-dimensional vertical column. The following calculations are to examine the potential of the overlying fractured tuff to accept the condensate.

For the simplified site geometry attached, evaluate the following:

1. Evaluate the volume of water mobilized from the *dryout* zone if the zone extends approximately 100 *m* above and below the repository. All water vapor will move upwards. Evaluate this *per* unit area of the repository and at the repository scale.

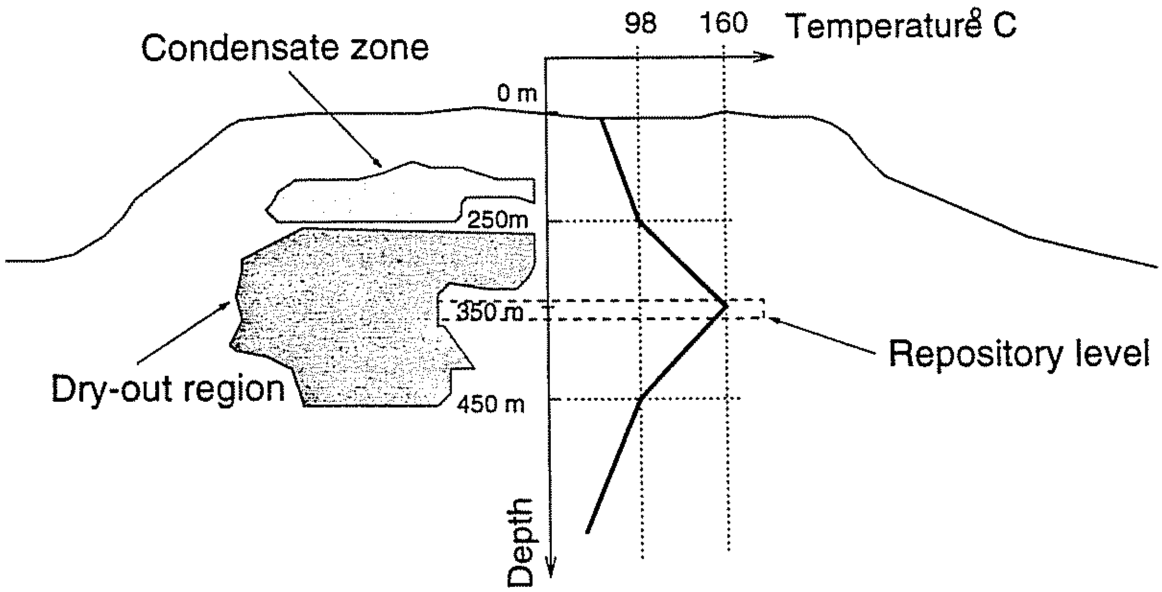
2. The moisture retention behavior in drying has been measured, as attached, but no data are available for imbibition. Use the imbibition data from the Leverett curves, to evaluate the ability of the overlying beds to accommodate the condensate released from the *dryout* zone. The data supplied should be sufficient. What height above the repository reaches its maximum water retention? Is there sufficient receptive volume? If so, how much larger could the *dryout* zone expand above the repository, and still have the condensate retained. If not so, how much must the upper *dryout* zone be shrunk to accommodate the condensate below ground level? Always assume the lower *dryout* region to be fixed at a depth of 450 *m*.

3. In reality the Yucca Mountain site receives an annual rainfall of about 5 mm/yr (in non-El Niño years!). If the presence of a repository prevents vertical drainage of this infiltration through the repository, how significant is its effect on the "volume problem" for condensate above the repository. If rainfall is increased to 100 mm/yr in a pluvial period, how is this result changed?

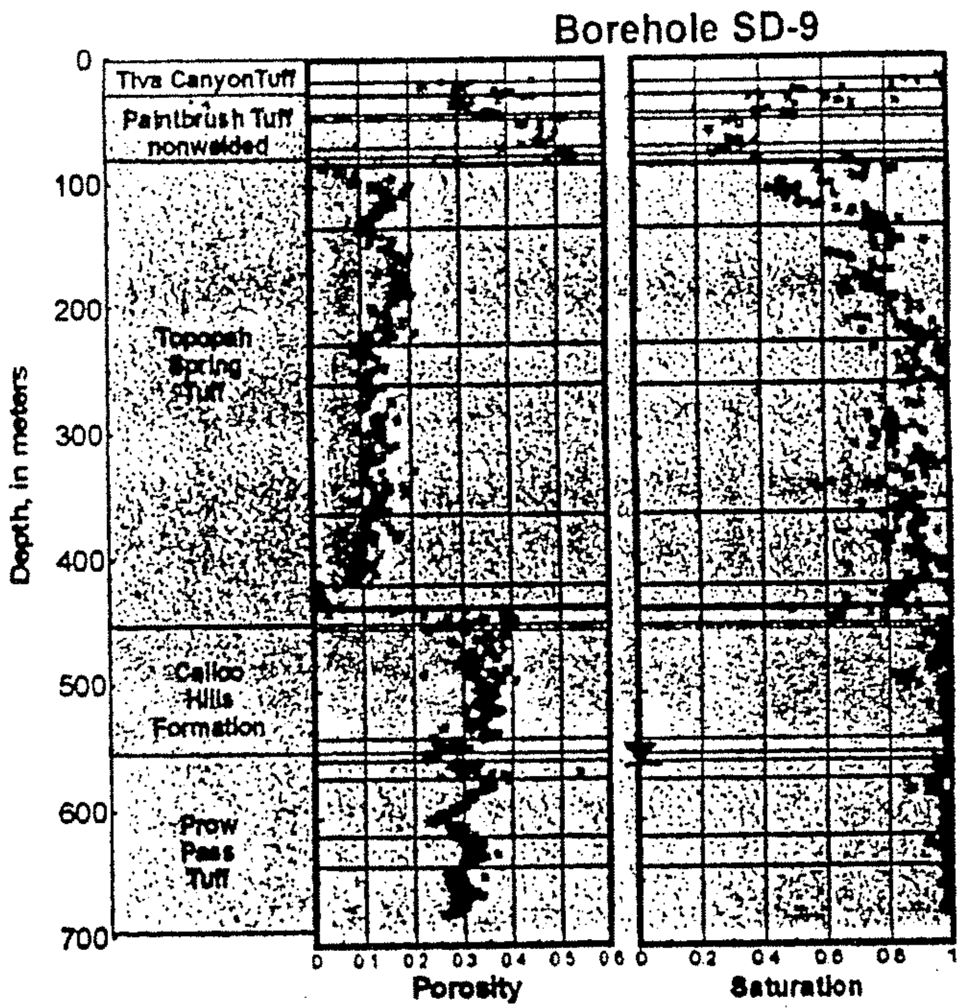
4. The tuffs are highly fractured (mean spacing between fractures, s, of 0.2 to 1.0 *m*), with bulk permeabilities in the range $10^{-12}m^2$ to $10^{-14}m^2$. The fractures are predominantly vertical, and well connected. Consider only continuous vertical fractures. How much of the condensate may additionally be held within the fractures? Note that bulk permeability, k, may be related to fracture aperture, b, as $k = \frac{b^3}{12s}$. Ignore infiltration from precipitation.

   What will be the maximum height to which the vertical fractures may saturate before it will reflux into the *dryout* region? How does this vary with choice of permeability and spacing?

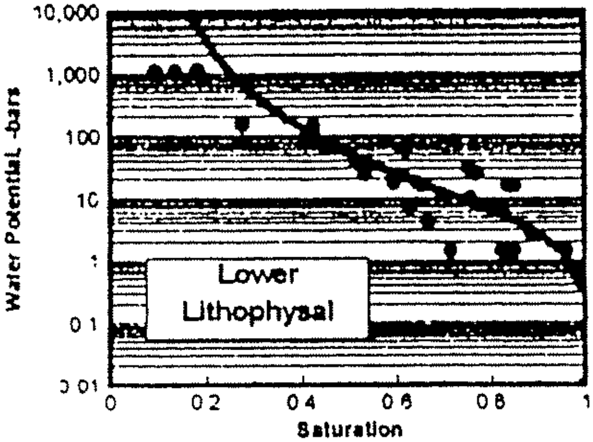
In all of these, state and justify your assumptions.



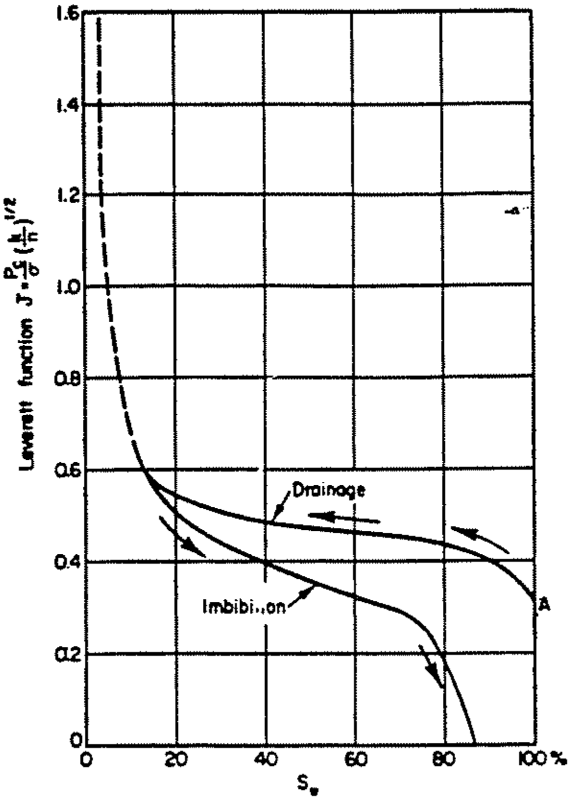
98
160
Temperature °C
Condensate zone
0 m
250m
350 m
Repository level
Dry-out region
450 m
Depth



Borehole SD-9
Tiva Canyon Tuff
Paintbrush Tuff nonwelded
Topopah Spring Tuff
Calico Hills Formation
Prow Pass Tuff
Depth, in meters
0
100
200
300
400
500
600
700
0 0.1 0.2 0.3 0.4 0.5 0.6
Porosity
0 0.2 0.4 0.6 0.8 1
Saturation



10,000
1,000
100
10
1
0.1
0.01
Water Potential, -bars
Lower
Lithophysal
0
0.2
0.4
0.6
0.8
1
Saturation



1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
Leverett function
Drainage
Imbibition
A
0
20
40
60
80
100%
S_w